
STATE COLLEGE OF WASHINGTON
AGRICULTURAL EXPERIMENT STATION
Pullman, Washington

Division of Plant Pathology



Virous Diseases of Greenhouse-Grown Tomatoes

By
Leon K. Jones and Grover Burnett

Bulletin No. 308

April, 1935

All bulletins of this Station are sent free to citizens of the State
on application to the Director

BOARD OF REGENTS

B. A. Perham, President.....	Yakima, Wash.
C. W. Orton.....	Sumner, Wash.
A. W. Davis.....	Spokane, Wash.
W. A. Ritz.....	Walla Walla, Wash.
S. A. Kimbrough.....	Spokane, Wash.
E. O. Holland.....	(President of the College, Secretary, e-officio)

EXPERIMENT STATION STAFF

E. O. Holland, Ph.D., President	Edward C. Johnson, M.A., Director
Wm. C. Kruegel, B.A., Treasurer	E. V. Ellington, B.S., Vice Director

Agricultural Engineering

L. J. Smith, M.E., Agricultural Engineer in Charge.
H. L. Garver, E.E., Investigator, Farm Electricity. ¹
P. C. McGrew, B.S., Agricultural Engineer, U.S.D.A. ²

Agronomy

E. G. Schafer, M.S., Agronomist in Charge.
E. F. Gaines, D.Sc., Cerealist. ²
A. L. Hafenrichter, Ph.D., Asst. in Farm Crops. ⁴
S. C. Vandecaveye, Ph.D., Soil Biologist.
L. C. Wheething, Ph.D., Associate in Soils.
G. O. Baker, M.S., Assistant in Soils.
O. E. Barbee, M.S., Assistant in Farm Crops.
Glenn M. Horner, M.S., Assistant in Soils.
Donald Douglas, B.S., Asst. in Agronomy.
Clarence Seely, B.S., Asst. in Agronomy.
Orville A. Vogel, M.S., Agent, U. S. D. A. ²
H. P. Singleton, M.S., Associate in Agronomy, Irrigation Branch Station, Prosser.
Carl A. Larson, Ph.D., Specialist in Irrigation Investigations, Irrigation Branch Station, Prosser. ²
W. A. Rockie, B.S., Scientist in Soil Erosion, U. S. D. A. ³

Animal Husbandry

Howard Hackedorn, B.S., Animal Husbandman in Charge.
Jerry Sotola, M.S., Asst. Animal Husbandman.
R. E. McCall, M.S., Assistant in Animal Husbandry.

Chemistry

J. L. St. John, Ph.D., Chemist in Charge.
Otto Johnson, M.S., Assistant Chemist.
Kermit Groves, Ph.D., Assistant Chemist.

Dairy Husbandry

E. V. Ellington, B.S., Dairy Husbandman in Charge.
H. A. Bendixen, M.S., Associate Dairy Husbandman.
N. S. Golding, Ph.D., Associate Dairy Husbandman.
J. C. Knott, M.S., Assistant Dairy Husbandman.
C. C. Prouty, M.S., Associate Dairy Bacteriologist.
R. E. Hodgson, M.S., Assistant Dairy Husbandman, Western Washington Experiment Station, Puyallup. ²
Harvey Murer, B.S., Research Dairy Chemist.

Entomology & Zoology

R. L. Webster, Ph.D., Entomologist in Charge.
James Marshall, M.S., Assistant Entomologist, Wenatchee.
Arthur J. Hanson, M.S., Assistant Entomologist, and Entomologist, Western Washington Experiment Station, Puyallup.

Farm Management & Agricultural Economics

Ben H. Pabols, M.S., Associate Agricultural Economist, Acting in Charge.
E. F. Dummeier, Ph.D., Agric. Economist.
R. B. Heffebower, Ph.D., Associate Economist.
Chester C. Hampson, M.A., Assistant Agricultural Economist.
Alden E. Orr, M.S., Asst. in Farm Management.

Home Economics

Florence Harrison, A.M., Home Economist in Charge.
Evelyn H. Roberts, M.S., Research Specialist in Home Economics.
Enid Sater, A.B., M.S., Research Specialist in Home Economics.

Horticulture

E. L. Overholser, Ph.D., Horticulturist in Charge.
O. M. Morris, M.S., Horticulturist.
F. L. Overley, M.S., Associate in Horticulture, Wenatchee.
C. L. Vincent, M.S., Asst. Horticulturist.
C. D. Schwartz, B.S., Research Assistant.
G. W. Young, B.S., Research Assistant.

Plant Pathology

F. D. Heald, Ph.D., Plant Pathologist in Charge.
L. K. Jones, Ph.D., Assoc. Plant Pathologist.
George W. Fischer, Ph.D., Asst. in Plant Pathology.
C. S. Holton, Ph.D., Agent, U. S. D. A. ³

Poultry Husbandry

John S. Carver, B.S., Poultry Husbandman in Charge.
Victor Heiman, Ph.D., Assistant in Poultry Husbandry.

Veterinary Science

J. W. Kalkus, D.V.S., Veterinarian in Charge, Western Wash. Exp. Station, Puyallup.
C. E. Sawyer, D.V.S., Research Veterinarian, Western Wash. Exp. Station, Puyallup.

Branch Stations

H. M. Wanser, M.S., Supt. Adams Branch Station, Lind.
H. P. Singleton, M.S., Superintendent, Irrigation Branch Station, Prosser.
D. J. Crowley, B.S., Specialist in Cranberry Investigations, Cranberry Investigations Laboratory, Long Beach.

Pacific Northwest Soil Erosion Station²

W. A. Rockie, B.S., Superintendent. ³
C. E. Deardorff, M.S., Acting Superintendent.
P. C. McGrew, B.S., Agricultural Engineer.
Arthur J. Johnson, Agent.

¹ In cooperation with the State Committee on the Relation of Electricity to Agriculture.


² In cooperation with the United States Department of Agriculture.

³ Temporarily transferred to U. S. Department of the Interior as Regional Director, Pacific Northwest Soil Erosion Control Project.

⁴ On leave.

TABLE OF CONTENTS

Introduction	5
Big Bud	5
Bunchy Top	6
Curly Top	6
Delphinium-virus Disease	7
Fern Leaf	7
Spot Necrosis	8
Spotted Wilt	9
Stripe	10
Veinbanding-virus Disease	10
Witches' Broom	10
Yellow Mosaic	11
Investigations on the Mosaic, Mottle, and Streak Diseases.....	11
Characters of the Viruses	11
Symptoms	11
Mosaic	11
Mottle	12
Streak	14
Methods of Infection	15
Seed	15
Mechanical contact	17
Use of tobacco by workmen	17
Handling potatoes	18
Potatoes in the soil	18
Host plants	19
Longevity in the soil	22
Insect transmission	27
Economic Importance	28
Control	33
Summary	34
Literature Cited	35



Digitized by the Internet Archive
in 2025

Virous Diseases of Greenhouse-Grown Tomatoes¹

Leon K. Jones and Grover Burnett²

INTRODUCTION

Virous diseases cause considerable loss to tomato growers throughout the State of Washington each year, and nearly complete failures of crops, caused by streak, were noted in greenhouses in the vicinity of Spokane, Washington, during the spring seasons of 1926 and 1927.

The following virous diseases of tobacco which are transferable to tomato plants may be of importance on the greenhouse-grown tomato crop: mild mosaic, white mosaic, severe mosaic, etch, etch plus, severe etch (30)³; tobacco mosaic, speckled mosaic, yellow mosaic, and bleaching mosaic (17). It has also been shown that each of these tobacco viruses when combined with the latent virus of potatoes in tomato plants will produce necrosis and death of parts of tomato plants. Three viruses that affect tobacco [ring mosaic (30), tobacco virus 9 (17), and stripe (1)] have also been noted as causing necrosis and death of parts of tomato plants that is similar to the condition known as streak. Brief descriptions are given of other virous diseases of tomato that may be of importance on the greenhouse-grown crop.

Big Bud

This virous disease (25) has been reported as occurring only in Australia where its prevalence varies from season to season. The outstanding symptoms are: dwarfing of the plant, with excessive branching due to a stimulation of the growth of axillary shoots; erection of the normally recurved fruit pedicels; enlargement of the calyx lobes; virescence of the petals; abnormalities in stamens and ovaries; and frequent floral proliferation.

The reported investigations on this disease show that: (1) the disease could not be transmitted by mechanical inoculation, but was readily transmitted by budding and grafting, the shortest incubation period being 28

³ The numbers in parentheses refer to the literature cited.

¹ The writers express their appreciation to Dr. F. D. Heald for helpful suggestions in the preparation of the manuscript.

² Formerly Research Assistant in Plant Pathology, Washington Agricultural Experiment Station, Pullman, Washington.

days; (2) no insect vectors of the disease have been discovered; and (3) possibly *Solanum nigrum* is a host plant.

Bunchy Top

The abnormal condition of tomato plants known as bunchy top (20) has been reported as being more or less generally distributed through certain low-lying districts of the Transvaal in South Africa. The disease is characterized by a cessation of growth at the branch extremities, with the result that the leaves become closely crowded together, giving the plant a bunched appearance; severe stunting of the plant, with various forms of leaf distortion; the development of brown streaks along the leaf veins; and subsequent formation of fruits that are small, somewhat distorted, and of no commercial value. Neither chlorosis nor mottling occurs as a result of this disease.

Reported investigations indicate that: (1) the disease is not carried in the seed or in the soil with which parts of diseased plants have been mixed; (2) it is readily transmitted to healthy plants by grafting, by juice inoculation, and by rubbing leaves or stems with macerated tissue of diseased plants; (3) insect transmission studies have failed to produce evidence of an insect vector; and (4) attempts to transfer bunchy top to tobacco by methods of grafting and leaf mutilation gave negative results.

The following measures are recommended as likely to be effective in the control of this disease: (1) the early removal of diseased plants; (2) the avoidance of successive handling of diseased and healthy plants; and (3) the prevention of infection of plants in the seed bed and subsequently in transplanting by using care not to handle diseased plants.

Curly Top

This virous disease, known as curly top, yellows, or blight, is best known through its destructive development on sugar beets, but species of plants in the following families are known to be susceptible to attack: *Chenopodiaceae*, *Leguminosae*, *Cucurbitaceae*, *Cruciferae*, *Umbelliferae*, *Solanaceae*, *Polygonaceae*, *Malvaceae*, *Lanaceae*, *Boraginaceae*, and *Valerianaceae* (27).

The beet leaf hopper (*Eutettix tenellus*) is responsible for the spread of this disease and the prevalence of these insects is a determining factor in the prevalence of the disease in any given season. Curly top is often noted in field-grown tomatoes in western Washington, but it is less prevalent there than in the more arid sections of the state and has been observed only once in Washington on greenhouse-grown tomatoes. The virus is sap-transmissible only with difficulty; accordingly the handling or contact of plants during cultural practices is probably of little or no importance in the spread of the disease.

A tomato plant is often killed if it becomes affected with the disease while small but when an older plant is attacked growth is retarded; the leaflets roll upward, become leathery, and turn yellow with purplish discoloration of the leaf veins; fruits ripen prematurely; and the plant may die.

If the disease should become abundant in greenhouse-grown crops, shading the plants, destruction of diseased plants and control of the leaf hoppers by fumigation are recommended as control practices.

The Delphinium-virus Disease

A virus found in delphinium (7) is capable of producing a disease of tomatoes by mechanical inoculation with macerated plant tissue. The virus has also been transmitted to apple of Peru, black nightshade, chickweed, prickly lettuce, cucumber, zinnia, horehound, dog fennel, shepherd's purse, petunia, and spinach.

The characteristic symptoms of the disease on tomato include dwarfing, veinclearing, downward rolling of leaflets, and curling of the leaves with a blotchy type of mottling that is due to the presence of irregular chlorotic areas. This virus in combination with the tobacco mosaic virus produces a disease quite similar to the disease known as streak, except that filiform-leaf production is abundant.

In addition to the symptoms produced by either virus alone, the delphinium virus, when combined with the latent virus of potato, gave a type of spot necrosis and killing of the lower foliage.

Fern-leaf

The disease (22) appears on tomato plants following inoculation with the cucumber-mosaic virus from macerated plant tissue, following the handling of plants by workmen, and especially following inoculation of the plants by the use of aphids (*Myzus persicae*).

The disease is reported as being quite common in occurrence but has not been observed to a damaging extent in the greenhouses of the State of Washington.

The characteristic symptoms of this disease are dwarfing and general chlorosis of the plants; spindling, filiform appearance of the leaves resulting from marked reduction of the lamina, often to such an extent that only the midrib is left, marked rolling and folding, excessive indentation that gave a polypinnate condition, and mottling of the leaves with light and dark green areas. The combination of the cucumber mosaic virus and the potato latent virus in tomato plants causes necrosis and death of parts of the tomato plants that is similar to the condition known as streak.

The host range of this virus includes many species of plants in the *Cucurbitaceae* and *Solanaceae* and it has been transmitted to spinach, poke-weed, and pigweed (*Amaranthus retroflexus*).

Three species of aphids, *Myzus persicae*, *Macrosiphum gei*, and *Aphis gossypii*, as well as the leaf beetles, *Diabrotica vittata* and *D. 12-punctata*, are capable of transmitting this virus from plant to plant.

Characters of the virus are that it remains active in dried plant tissue for only a short period of time, and in extracted cell sap for three days or less; and that it is inactivated by exposure to a temperature of 60-70° C. for 10 minutes.

Spot Necrosis

The disease (8) known as rugose mosaic of potato which is produced by combining the veinbanding and potato latent viruses in the potato plant may be transferred to tomato plants by mechanical con-



Fig. 1. Spot necrosis—mottling of tomato leaf with light and dark green areas produced by inoculation with the veinbanding and potato latent viruses.

tact and juice inoculation while the veinbanding virus may also be transmitted by aphids. Leaves on affected tomato plants at first may show only a faint mottling similar to that produced by the potato latent virus alone. The light green interveinal tissue gradually becomes pale yellow, especially on the older leaves (Fig. 1), and brown necrotic spots may appear in the older leaves followed by yellowing and death of the lower foliage.

Since spot necrosis is primarily a disease of potatoes no soil harboring volunteer potatoes should be used in the greenhouse, and the handling of potatoes previous to the handling of tomato plants should be avoided.

Spotted Wilt

A very destructive virous disease of tomatoes has been reported from all the states of Australia (24) and a similar disease has been reported from Wisconsin, California, and Oregon. Tomato plants showing symptoms associated with this disease were noted in two greenhouses in western Washington during the spring of 1934.

Bronzing of the upper surface of the younger leaves is followed by cessation of growth and dwarfing of the plants. Irregular to circular brown necrotic spots may appear on the leaves, often the upper part of the plant is killed, and occasionally the whole plant dies. Pronounced symptoms, consisting of paler red, often yellow, or more rarely white areas which have varied shapes ranging from irregular mottling to distinct concentric circles, sometimes appear in the normal red skin of the tomato fruit. Plants attacked in the early stages of growth usually bear no fruit.

Characters of the spotted wilt virus are that it is transmissible by gently rubbing macerated diseased tissue over foliage of healthy plants and by two species of thrips (*Frankliniella insularis* and *Thrips tabaci*); that it has a wide host range, having been transmitted to species of plants in 17 families; that it is rapidly inactivated by aging in expressed juice, remaining viable for only three or four hours at room temperature; and that it is inactivated when exposed to a temperature of 42° C. for 10 minutes.

Investigations in Australia lead to the conclusion that the virus is not carried in seed; however, the development of the disease in a greenhouse in Oregon leads to the conjecture that the virus was carried in seed introduced from England (21). Accordingly it may be a very poor practice to obtain seed from localities where the disease is known to be present.

If the disease appears in greenhouse plantings the following control measures are recommended:

1. Avoid handling diseased plants while working with healthy plants.
2. Pull out and destroy diseased plants when noted.
3. Fumigate at frequent intervals with hydrocyanic acid gas or calcium cyanide to control thrips.

Stripe

A virous disease which has some of the characters of mosaic as well as some of the characters of streak has been described in England and given the name stripe or glasshouse streak (1).

The characteristic symptoms of stripe are: (1) dark longitudinal streaks on the stems, with brown areas in the pith and cortex; (2) mottling of the leaves, consisting of light and dark green areas, similar to that caused by tomato mosaic; and sometimes (3) round or irregular, sunken, dark brown blotches on the fruit.

The Veinbanding-virus Disease

This virus which is commonly found in potato and tobacco plants produces very mild symptoms on tomato plants (8). The leaves of affected plants have pale green veins and a barely visible mottling consisting of irregular pale green areas between the veins, often not sufficiently pronounced for definite diagnosis. The virus appears to have little or no detrimental effect on the growth of the tomato plant; however, the combination of this virus with the potato latent virus in tomato plants produces the diseased condition known as spot necrosis (Fig. 1).

The veinbanding virus may remain active in dried plant tissue not to exceed 50 days and for about three days in expressed plant juice at room temperature. The virus is also inactivated by exposure to temperatures of 45-50° C. for 10 minutes.

Witches' Broom

The witches' broom disease of potato has been transferred to tomato by inarch grafting (31). The symptoms produced include narrowing, rugosity, and dwarfing of the leaves and of the plant. The terminal leaflets usually turn light yellow, pale green, hyaline, or purple.

The witches' broom disease has not been transmitted from plant to plant by mechanical contact or by macerated plant tissue inoculation and investigators have been unable to demonstrate that any insect is a carrier of the virus. The prevalence of the disease on potatoes during some seasons would indicate that some insect is capable of transmitting the virus.

Yellow Mosaic (*Aucuba mosaic*)

A disease which appears to be quite similar to common tomato mosaic, with the exception that the light areas in the mottled leaves are larger and intensified in color, is commonly present on tomato plants. In severe cases almost the whole leaf surface is pale yellow or white, with small, dark green, raised or blister-like areas scattered in the lighter area. Jensen (16) is of the opinion that some of the yellow mosaic of solanaceous plants prevalent in commercial fields and greenhouses may have originated in yellow spots on leaves of plants having tobacco mosaic.

The fruit produced on plants affected with yellow mosaic may show no symptoms or it may be mottled with light and dark green areas.

The virus has a number of characters similar to those of the tobacco mosaic virus; it is sap transmissible, retains its activity in expressed plant juice for a year or more at room temperature, and is inactivated by a temperature of 90° C. for 10 minutes.

INVESTIGATIONS ON THE MOSAIC, MOTTLE, AND STREAK DISEASES

Observations on greenhouse-grown tomatoes were made during the years 1928-34, and specimens of virus-infected tomato plants were collected from which inoculation tests were made on tobacco, tomato and *Datura stramonium* plants in the Experiment Station greenhouse in Pullman, Washington. These observations and tests demonstrated that three diseases are the most commonly found viroous troubles in the greenhouses, as follows: (1) tomato mosaic, which is identical with common tobacco mosaic (tobacco mosaic virus No. 1); (2) mottle mosaic, produced on tomato plants by the latent virus that is present in practically all potatoes of commercial varieties; and (3) the streak disease, which is caused by a combination of the tomato mosaic virus and the latent virus of potato.

Characters of the Viruses

The exact nature of the viruses that cause disease in plants is unknown and they are classified largely according to symptoms produced, although various physical and chemical tests have been shown to be of value in their identification. Some of the characters of the mosaic, mottle, and streak viruses used in these studies are listed in Table 1.

Symptoms

Mosaic. This disease is characterized by the presence of light, and often raised, dark green areas in the leaf tissue (Fig. 2). The affected

leaves are often puckered, narrowed, and smaller than normal, and show more numerous and deeper marginal indentations, while the entire plant may appear somewhat spindling and paler than normal.



Fig. 2. Tomato mosaic—mottling, puckering and attenuation of tomato foliage. The young shoot at the left is healthy.

Mottle. The latent virus of potatoes, depending on its source and virulence, is capable of producing somewhat variable symptoms on tomato. The disease may show as faint, irregular areas of pale green in the interveinal leaf tissue (Fig. 3), sometimes so faint that they are difficult to recognize or as irregular, pale green to yellow interveinal areas in contrast with the darker green along the larger veins. Dead, brown, scatter spots may sometimes appear on the lower leaves (Fig. 4), but there is little or no dwarfing of affected plants.

Table 1. Specific Characters of the Tomato Mosaic, Mottle, and Streak Viruses

Virus	Longevity in vitro	Longevity in dry plant tissue	Tolerance to dilution in water	Tolerance to temperature ¹
Mosaic virus	Indefinite ²	Indefinite ³	1/100,000,000	90° C.
Mottle virus	80 days	286 days ⁴	1/10,000	70° C.
Streak viruses		1251 days ⁴		

¹ Inactivated in expressed cell sap by a 10-minute exposure to the given temperature.

² The virus is still active in expressed cell sap stored in ice box for eight years.

³ The virus is still active in dry mosaic infected tobacco leaves after five years storage.

⁴ See Burnett (6).



Fig. 3. Mottle—faint lighter green areas in the interveinal tissue of tomato leaf produced by inoculation with the potato latent virus.

Streak. The combination of mosaic and mottle in the tomato plant produces a very serious disease with an abundance of dark brown to black irregular, dead areas, 1 mm. to 1 cm. in diameter on the foliage (Fig. 5), that may coalesce and cause the death of leaflets and leaves. Black to brown, somewhat sunken, elongated lesions are produced on stems and leaf petioles, the fruit may be dwarfed and spotted with brown, raised, greasy, superficial lesions, 2-5 mm. in diameter that seldom extend below the epidermal cells (Fig. 5), and



Fig. 4. Mottle—dead, brown, spots may appear in the lower leaves of tomato plants inoculated with the latent virus from potato plants.

the set is greatly reduced. When older plants become affected, extreme necrosis of foliage develops for two to three nodes above the point of inoculation (Fig. 6), while the foliage below the point of inoculation remains relatively normal in appearance, which allows one to determine quite definitely the age of the plant at the time it became affected.



Fig. 5. Streak—black to brown, sunken spots appear in the leaves and stems and raised, brown, greasy spots may appear on the fruit of tomato plants inoculated with the tobacco mosaic virus and the potato latent virus.

Methods of Infection

Seed. Many investigators in the United States have tested large numbers of seeds collected from mosaic-infected tomato plants and their conclusions indicate that the common mosaic virus is not transmitted through the seed. However, results of investigations reported in England (5) and in Canada (4) tend to show that mosaic and streak may be carried in the seed.

Results of tests made with seed collected from virus-infected and virus-free plants in the greenhouse in 1933 (Table 2), show that the viruses were not transmitted through the seed.

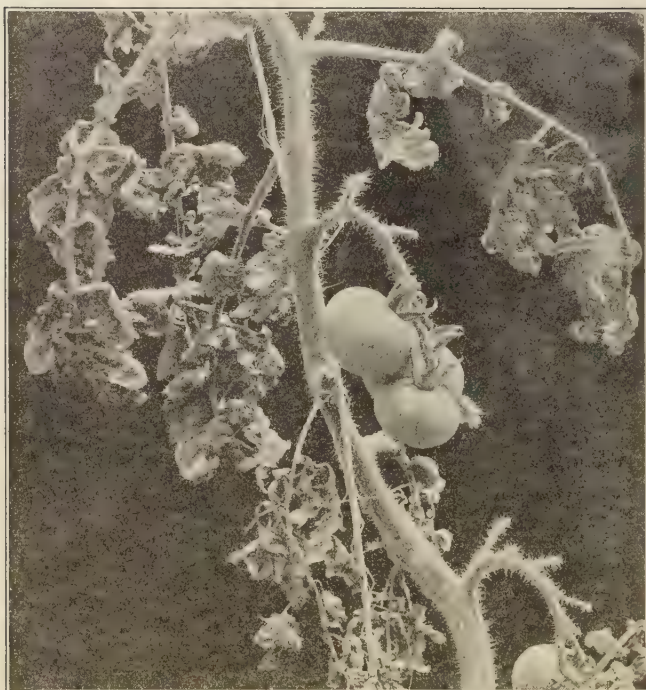


Fig. 6. Streak—on older tomato plants extreme necrosis of foliage develops for two or three nodes above the point of inoculation with the tobacco mosaic and potato latent viruses.

Table 2. Number of Virus-free Plants Grown from Seed of Sutton's Best-of-All Collected from Virus-infected Plants

Condition of plants producing seed	Number of plants produced from seed	
	Spring of 1933 ¹	Fall of 1933 ²
Mosaic infected	1353	350
Mottle infected	2014	
Streak infected	526	
Virus-free	3021	150

¹ Plants grown in greenhouse until first blossom clusters had formed.

² Plants grown to maturity and the fruit harvested in greenhouse from June 29, 1933 to January 5, 1934.

Numerous observations of the mosaic, mottle, and streak diseases on tomatoes in greenhouses have shown that these diseases do not appear on the plants until after they have been handled by workmen in transplanting from the flats or in the pruning operations after the plants have been benched.

The results of tests with seed (Table 2), as well as observations in greenhouses, indicate that the mosaic, mottle, and streak diseases are not carried in the seed. However, since there is a difference of opinion in the literature on this matter it is advisable to collect seed from virus-free plants only.

Mechanical Contact. The mosaic virus, the mottle virus, and the combination of the two viruses in streak are very readily transmitted by mechanical contact of injured portions of a diseased plant with a healthy plant. Extreme injury of the plants is not necessary, in fact a lower percentage of transfer of the viruses may be obtained by excessive rupturing and injuring of the plant than is the case when only slight abrasion of the epidermal cells or breaking of the leaf hairs takes place. The handling of plants by workmen in transplanting, pruning, and tying operations and the possible contact of foliage from careless use of the hose may spread the viruses from a diseased plant to healthy plants. With these facts in mind it is advisable to remove carefully the diseased plants from tomato beds without allowing the diseased foliage to come in contact with healthy plants during removal. If the plants are large before the disease is noted and cannot be removed without coming in contact with healthy plants, it is advisable to put red tags or streamers of cloth on the diseased plants so that the workmen may avoid touching the diseased plants while following cultural practices necessary in the growing of tomatoes under glass.

It has also been shown that careful washing of the hands with soap and water following the pruning of a diseased plant will free the hands of these viruses. Frequent washing of the hands with soap and water by the workmen while working with tomatoes is a good precautionary measure to reduce the rate of spread of these viruses.

Use of Tobacco by Workmen. It has been shown that various brands of smoking and chewing tobacco are often carriers of the mosaic virus (29). Observations made in the greenhouses lead to the conclusion that the use of tobacco, especially cigarettes or chewing tobacco, by workmen while working with tomato plants, is probably the main source of infection with the mosaic virus. Several cases of infection in the plant beds were traced to inoculation of plants through the use of cigarettes by workmen at the time of potting from the flats or transplanting into the beds. Another case is on record where the

workman continually chewed tobacco, and for several years while this man had charge of the tomato houses serious loss from mosaic and streak was noted in the crops. A new man was placed in charge of the tomato crop in 1928 and no damage from mosaic or streak has been observed in the tomato crops since this shift was made.

Another possible method of introducing tobacco mosaic into the greenhouse crop is the handling of plants by visitors. A good precautionary measure adopted by many growers is the posting of signs to the effect that tobacco should not be used in the tomato-growing section of the greenhouse and that hands should be washed with soap and water before handling the tomato plants.

Handling of Potatoes. The latent virus, which is the cause of the mottle disease of tomatoes, is found in practically all potatoes grown in Washington. It has been shown that a low percentage of tomato plants become infected with the latent virus following inoculation with macerated potato tuber tissue (8). Further tests were made to determine whether or not this virus may be introduced into tomato plants following the handling of tubers. The results of these tests (Table 3) show that the virus causing the mottle disease may be carried on the hands of workmen sprouting, handling, or paring potato tubers previous to working with tomato plants, and that careful washing of the hands with soap and water following the handling of potatoes destroys the virus.

Potatoes in the Soil. The latent virus of potatoes is often introduced into the greenhouse through volunteer potato plants appearing in benches filled with soil in which potatoes have previously been grown.

On January 16, 1931 two ground beds 7x20 feet were planted with 70 tomato plants each (Table 6). In one bed a volunteer potato plant affected with the latent virus was allowed to grow. On March 14 a stream of water was so directed as to forcibly knock the potato plant against the foliage of a tomato plant and typical mottle symptoms appeared on this tomato plant by March 28 (Table 4). Through the ordinary cultural practices of pruning, tying, and watering all the tomato plants in the bed became affected with the mottle disease by May 1 while the other bed of 70 plants remained free from the mottle disease throughout the growing season. Care was used to wash the hands thoroughly with soap and water before working with the plants in the bed free from the mottle disease.

Table 3. Percentage Transfer of the Latent Virus Caused by Handling Potato Tubers Previous to Handling Tomato Plants

Method of handling ¹	Test No.	No. tomato plants handled	Per cent of tomato plants infected with the latent virus
Tubers vigorously rubbed in the hands	1	25	0
"	2	25	4
"	3	25	0
"	4	25	0
Tubers peeled	5	25	0
"	6	25	4
"	7	25	0
Tubers injured and rubbed vigorously in hands	8	25	0
"	9	25	0
Sprouts removed from tubers	10	25	0
"	11	25	4
"	12	25	8
"	13	25	0
Control, hands washed with soap and water previous to each type of test	14	25	0
"	15	25	0
"	16	25	0
"	17	25	0

¹ Hands allowed to dry for 10 minutes following handling of potatoes before the tomato plants were handled.

Host Plants. The mottle virus and the mosaic virus may be present in a number of different species of plants (Tables 5 and 6), some of which may be weeds or even cultivated plants in or near the greenhouse. The presence of these viruses in such plants is a possible source of infection to the tomato plants.

Table 4. The Effect of the Mottle Disease on Yield of Tomato Fruit

Planting	No. of plants	Total yield		Average production per plant	
		No. of fruits	Weight of fruits Pounds	No. of fruits	Weight of fruits Pounds
West bed ¹	70	2376	552	33.9	7.9
East bed (control)	70	2711	561	38.8	8.0

¹ One plant infected with the latent virus of potato on March 28; the disease had spread through cultural practices to all the plants in this bed by May 1, 1931.

Table 5. Plants Known to be Susceptible to Infection by the Potato Latent Virus¹

1. *Amaranthus retroflexus* L.—Pigweed
2. *Datura stramonium* L.—Jimson weed
3. *Hyoscyamus niger* L.—Black henbane
4. *Lycopersicon esculentum* Mill.—Tomato
5. *Nicandra physaloides* Gaertn.—Apple of Peru
6. *Nicotiana rustica* L.—Tobacco
7. *Nicotiana glutinosa* L.—Tobacco
8. *Nicotiana tabacum* L.—Common tobacco
9. *Solanum dulcamara* L.—Bittersweet
10. *Solanum miniatum* Bernh.
11. *Solanum nigrum* L.—Black nightshade
12. *Solanum tuberosum* L.—Potato

¹ See Jones, Anderson, and Burnett (19).

Table 6. Plants Known to Be Susceptible to Infection by the Tobacco Mosaic Virus¹

1. *Antirrhinum majus* L. —Snapdragon
2. *Beta vulgaris* L. —Garden and sugar beets
3. *Beta vulgaris* var. *cicla* L. —Swiss chard
4. *Brassica alba* Raberh. —Mustard
5. *Brassica rapa* L. —Turnip
6. *Capsicum frutescens* L. —Pepper
7. *Cynoglossum amabile* S. & D. —Chinese forget-me-not
8. *Daucus carota* var. *sativa* DC. —Carrot
9. *Delphinium consolida* L. —Larkspur
10. *Digitalis purpurea* L. —Foxglove
11. *Dimorphotheca aurantiaca* DC. —Cape marigold
12. *Emilia sagittata* (Vahl.) DC. —Tassel flower
13. *Fagopyrum esculentum* Gaertn. —Buckwheat

Table 6 (Continued). Plants Known to Be Susceptible to Infection by
the Tobacco Mosaic Virus¹

14. *Hyoscyamus niger* L. —Black henbane
15. *Ipomoea tricolor* Cav. —Morning glory
16. *Linaria cymbalaris* (L.) Mill. —Kenilworth ivy
17. *Lycopersicon esculentum* Mill. —Tomato
18. *Lycopersicon pimpinellefolium* Mill.
19. *Martynia louisiana* Mill. —Unicorn plant
20. *Nicandra physaloides* Gaertn. —Apple of Peru
21. *Nicotiana acuminata* Hook. —Tobacco
22. *Nicotiana alata* Link and Otto
23. *Nicotiana clevelandii* A. Gray.
24. *Nicotiana glauca* R. Grah
25. *Nicotiana glutinosa* L.
26. *Nicotiana langsdorffii* Schrank
27. *Nicotiana longiflora* Cav.
28. *Nicotiana palmeri* A. Gray
29. *Nicotiana paniculata* L.
30. *Nicotiana quadrivalvis* Pursh.
31. *Nicotiana rusbyi* Britton
32. *Nicotiana rustica* L.
33. *Nicotiana sanderae* Sander
34. *Nicotiana suaveolens* Lehm.
35. *Nicotiana sylvestris* Speg. and Comes
36. *Nicotiana tabacum* L. —Common tobacco
37. *Nicotiana tomentosa* Ruiz. and Pav.
38. *Nicotiana trigonophylla* Dun.
39. *Pentstemon barbatus* Roth. —Beard-tongue
40. *Petunia* spp. —Petunia
41. *Phacelia campanularia* Gray
42. *Phacelia grandiflora* (Benth.) Gray
43. *Phacelia parryi* Torr.
44. *Phacelia tenacetifolia* Benth.
45. *Phacelia whitlavia* Gray —California blue bell
46. *Phaseolus vulgaris* —Green pod refugee bean
47. *Phlox drummondii* Hook. —Phlox
48. *Physalis alkekengi* L. —Ground cherry
49. *Physalis angulata* L.
50. *Physalis peruviana* L.
51. *Proboscidea louisiana* Woot. and Stand.
52. *Quamoclit pennata* Bojir —Cypress vine
53. *Scrophularia marylandica* L. —Maryland figwort
54. *Solanum carolinense* L.—Horse nettle
55. *Solanum melongena* L.—Egg plant
56. *Solanum miniatum* Bernh.
57. *Solanum nigrum* L. —Black nightshade
58. *Solanum tuberosum* L. —Green Mountain potato
59. *Spinacia oleracea* L. —King of Denmark Spinach
60. *Tagetes patula* L.—French Marigold
61. *Tetragonia expansa* Murr. —New Zealand spinach
62. *Verbascum thapsus* L. —Mullein
63. *Zinnia elegans* Jacq. —Zinnia

¹ See Grant (12) and Holmes (15).

Longevity in the Soil. There are two general practices used in the culture of tomatoes under glass: (1) the growing of a spring crop with the plants in the beds from January to July, followed immediately by a fall or early winter crop with the plants in the beds from July to January; (2) the growing of a spring crop of tomatoes, followed by chrysanthemums or some other benched or potted crop during the months of July to January. Growers using their greenhouses continuously for tomato culture have been especially anxious to know whether the viruses can remain active in the soil.

Early investigators were of the opinion that the soil was an important source of infection but Allard (2) concluded that mosaic material in the soil did not infect plants growing therein.

Further investigations have shown that tomato mosaic will remain active in greenhouse soils for at least 70 days and from four to six weeks in field soils (10), while Johnson and Ogden obtained evidence that the tobacco mosaic virus may overwinter in the soil and that moist, well aerated soil favors the inactivation of the virus as compared with dry, compact, or waterlogged soils (18).

Young tomato plants were set at weekly intervals in soil that had previously grown streak-infected tomato plants (Table 7). Some of the plants were placed in soil that was watered soon after the diseased plants had been removed. Other plants were placed in soil that was kept dry following the removal of the diseased plants until

Table 7. The Results of Planting Tomato Plants at Weekly Intervals in Soil from Which Streak Tomato Plants had been Removed¹

Date of planting	Number of tomato plants showing mosaic ²			
	Soil watered, and kept moist		Soil dry until planted	
	Bed No. 1	Bed No. 2	Bed No. 1	Bed No. 2
July 25	1	0	0	0
August 1	4	1	0	0
August 8	0	0	0	0
August 15	0	0	0	0
August 22	1	0	0	0
August 29	0	0	0	0

¹ Tomato plants affected with streak were pulled out and all foliage raked from the soil July 25, 1932 following which 96 young tomato plants were set in the soil at weekly intervals, 24 plants in each of the beds under moist soil and dry soil conditions. The plants were observed until September 24, 1932 to obtain the above results.

² The mottle or streak disease did not develop in any of the plants.

Table 8. The Effect of Crop Rotation on the Recovery of the Streak-producing Viruses from the Soil¹

Planting bed	Season and crop grown					
	Jan. 19, 1929 to July 1, 1929	July 1, 1929 to Jan. 15, 1930	Jan. 15, 1930 to July 1, 1930	July 1, 1930 to Jan. 15, 1931	Jan. 15, 1931 to July 1, 1931	Jan. 15, 1932 to July 1, 1932
Bed 1	Tomatoes (streak) ²	Dry fallow	Tomatoes (healthy) ³	Chrysanthemums	Chrysanthemums	Tomatoes (healthy) ⁴
Bed 2	Tomatoes (healthy)	Dry fallow	Tomatoes (streak) ²	Chrysanthemums	Chrysanthemums	Tomatoes (healthy)
Bed 3	Tomatoes (streak) ²	Beets	Tomatoes (healthy) ³	Chrysanthemums	Chrysanthemums	Tomatoes (healthy) ⁴
Bed 4	Tomatoes (healthy)	Beets	Tomatoes (streak) ²	Chrysanthemums	Chrysanthemums	Tomatoes (healthy)

¹ The 64 to 75 tomato plants grown in each bed each season were spaced 16 to 18 inches and common greenhouse cultural practices were followed in maturing a crop of fruit.

² Three plants in each bed were inoculated with the tobacco mosaic and the potato latent virus three to four weeks following planting.

The streak disease spread to all of the plants through cultural practices before the crop was matured.

³ Tobacco mosaic, mottle, or streak diseases did not develop in these plants by infection from the soil that had grown streak or mottle infected plants the previous season.

⁴ One plant was inoculated with the mottle virus by mechanical contact with a volunteer potato plant, March 28, 1931, and the mottle virus spread to all the plants in this bed through cultural practices before the crop was matured.

reset with the healthy young plants. Following planting the soil was kept moist around the young plants regardless of the moisture condition of the soil before replanting.

The results of these tests show that young tomato plants set in beds from which streak-infected tomato plants have been removed may become infected with tobacco mosaic if set in the beds even five weeks after the removal of the diseased plants. This appears to be especially the case if the soil is kept moist following the removal of diseased plants. Neither mottle nor the streak disease developed on any of the young plants set in soil at weekly intervals following removal of streak-infected plants.

During the three seasons of 1929-1932 rotation of crops was followed in ground benches according to common greenhouse practice. The beds were 7x20 feet and were planted with 64 to 75 tomato plants from January to July, and for approximately the next six months period each year (July to January) chrysanthemums were grown in the beds with the exception of one year when dry fallow or beet culture was followed (Table 8). Each season the plants in two of the beds were inoculated with the streak or the mottle virus and the plants in two of the beds, where the streak or mottle disease had been present the previous year, were left uninoculated (Table 8).



Fig. 7. Healthy tomato plants—the mosaic, streak and mottle viruses did not remain active in the soil when a six month's period of rotation of crops was practiced.

The results of these tests show that the mosaic, streak, and mottle viruses were inactivated in the plant tissue in the soil when a six-months period of rotation of crops was followed in the greenhouses (Figs. 7 and 8).



Fig. 8. Streak-infected tomato plants—three plants were inoculated with the streak viruses one month after benching and the disease was spread to the remaining plants in the bed through cultural practices.

It has already been noted (Table 1) that the tobacco mosaic virus may remain active indefinitely in dried tomato or tobacco plant tissue and that the potato latent virus when dried alone in plant tissue was found to be infective 286 days in tobacco, 263 days in potato, but not more than 50 days in tomato. The latent virus when dried in streak-infected tomato foliage may remain infective longer than when dried alone and has been recovered from potato, tomato, and tobacco foliage that had been dried for periods of 352, 1251, and 618 days, respectively (8).

A further test was made to determine the longevity of the streak viruses in the tops and roots of tomato tissue in the soil as well as under air-dry conditions. The tomato plants were inoculated with the potato latent (mild) and tobacco mosaic viruses September 24, 1932, and the plants all became affected with the streak disease from which diseased roots and tops were collected October 31, 1932. The collected

Table 9. The Recovery of the Mosaic and Mottle Viruses by Inoculation to Tomato from Streak-infected Tomato Plant Tissue¹

Inoculation to tomato plants at weekly intervals ²	Condition of storage of the streak infected plant tissue						
	In soil, 4 inches deep			Dried in paper bags		Roots left in dry soil after removal of tops	
	Soil wet	Soil dry	Roots	Tops	Roots		Tops
November 7	T—S ³		T	T	T—S	T—S	
November 14	T		T	T	T—S	T	
November 21	T		T	T—S	T	T—S	
November 28	T		T	T	T—S	T	
December 6	T		T	T	T	T	
December 13	T		T	T	T	T	
Development of mosaic on tomato plants set in soil ⁴	0	0	2T	0		0	

¹ Tomato plants noted in Table 4 were inoculated with streak viruses September 24, 1932 and diseased plant tissue collected October 31, 1932 for storage.

² Portions of each stored plant tissue were removed at weekly intervals and used as inoculum on ten tomato plants.

³ T— recovery of tobacco mosaic on inoculated plants. S = recovery of the streak disease on inoculated plants;

⁴ Forty tomato plants were set in the soil where each series of streak-infected roots and tops had been stored for 61 days.

material was placed in the soil or stored in paper bags in the greenhouse (Table 9), and portions were removed at weekly intervals to be used as inoculum on tomato plants. Also on January 1, 1933, 40 tomato plants were set in the soil where each series of roots and tops had been stored.

The results of these tests show that the tobacco mosaic virus remained infective in streak-infected tomato tops and roots in the soil for at least six weeks and probably as long as the diseased plant tissue remained undecayed. The latent virus in the streak-affected plant tissue remained active for three weeks in two of the tests and for only four weeks in the air-dried plant tissue.

Even though the tobacco mosaic virus remained active in the diseased plant tissue in the soil, less than one per cent of the 160 tomato plants set in the soil where the diseased tissue had been stored for 61 days contracted the mosaic disease. These results as well as the results reported in Table 7 show that, even though mosaic-infected plant tissue remains infective in the soil, a very low percentage of tomato plants set in such soil will contract the disease. Low percentages of infection from soil contamination, however, may account for later heavy infection in the beds as a result of rapid spread of the disease by cultural practices. The results of these tests are in accord with the statement of Johnson and Ogden (18), "Tobacco plants do not ordinarily become easily or rapidly infected from mosaic-infected soil. Infection is rather gradual throughout the season."

Insect Transmission. Insects have often proved to be important agents in the spread of virous diseases, and the control of insect vectors accordingly is an important measure of reducing losses. It has been demonstrated that the species of aphids capable of transmitting tobacco mosaic from tomato plants during the process of feeding are *Myzus pseudosolani*, *Myzus persicae*, *Macrosiphum tabaci*, and *Macrosiphum solanifolii* (2, 3, 14).

The investigations reported by Cleveland (9) lead to the conclusions: (1) That leaf hoppers may be capable of transmitting tomato mosaic but such transmission is of little importance for the occurrence of leaf hoppers on tomato is limited and sporadic; (2) that the onion thrip (*Thrips tabaci*) is probably capable of transmitting tomato mosaic to a limited extent; (3) that the common red spider is apparently capable of transmitting the disease under conditions where the transfer of strong infestation is brought about, but it is doubtful that this takes place naturally; and (4) that there is little or no evidence that the white fly is capable of transmitting tomato mosaic.

The mealy bug, *Pseudococcus citri* (23), and the tobacco hornworm, *Protoparce sexta* (11), have been reported to be vectors of tobacco mosaic.

No investigators have been able to show that any insects are vectors of the potato latent virus that causes the mottle disease of tomato, and it has not been demonstrated that any insect is capable of transmitting the streak disease caused by the combination of the tobacco mosaic and the potato latent viruses.

Economic Importance

It has been reported that mosaic may cause a loss in yield of fruit of as much as 54 per cent under field conditions and as much as 24 per cent in greenhouses, and that the degree of loss is largely determined by the earliness of infection of the plants (13).

During the spring seasons of 1929, 1930, and 1931 tests were made in the greenhouse at the State College of Washington to determine the rate of spread and economic importance of the mosaic, streak, and mottle diseases. Ground beds 7 x 20 feet were planted each season in January with 64 to 75 healthy tomato plants which were spaced 16 by 18 or 20 inches apart. Each season the plants were tied, pruned to one stem, watered and fertilized until the crop was matured, and harvested according to common greenhouse practices (Table 8). The greenhouse was fumigated at frequent intervals with nico-fume powder for insect control.

Each season the seed was planted in flats towards the end of November and the young plants were transplanted into the four ground beds about January 15. Three plants in the center row of each of two beds were inoculated with the viruses of the mosaic and mottle diseases about one month after the plants were placed in the beds by rubbing foliage of tobacco plants affected with each of the viruses over the foliage of the tomato plants. The plants were tied up to overhead wires one week after transplanting and the first pruning was done about three weeks after transplanting. Following the first pruning the plants were pruned and twisted around the strings at 7- to 10-day intervals. At each pruning time the plants in the two uninoculated beds were always pruned first and the hands were washed thoroughly with soap and water twice during the pruning of the plants in each bed and also before starting to prune in each bed.

Mosaic or streak symptoms appeared on the inoculated plants from 10 to 15 days after inoculation and streak became most marked for two or three nodes near the point of inoculation by the development of necrosis in the mottled foliage and definite brown streaks on the leaf petioles and stems (Fig. 6). After the streak symptoms appeared in marked form extreme mosaic mottling, necrotic areas, and attenuation of leaves was noted on the new growth. Practically no fruit of value developed on the streak-infected plants above the point of inoculation, and the fruit on the plant below the point of inoculation

Table 10. Results of Experiments to Determine the Effect of Streak on the Yield of Greenhouse Tomatoes. Pullman, Washington, 1929¹

Condition of plants	No. of plants	Total yield		Average production per plant			Average weight per fruit Pounds
		Number of fruits	Weight of fruits Pounds	Number of fruits	Percentage reduction	Weight of fruits Pounds	
House 1—Healthy	64	2895	519	45.2		8.10	0.179
House 2—Healthy	64	2757	472	43.1		7.37	0.171
House 3—"Streak" infected ²	57	2184	359	38.3	13.3	6.14	0.159

¹ Best-of-All (Sutton's) tomato plants set in ground beds January 16, 1929.

² Three plants were inoculated with the tobacco mosaic virus and the latent virus of potato, February 13, 1929. All plants in this bed had contracted the streak disease by May 15 as a result of transmission by cultural practices.

Table 11. The Rate of Spread of Tomato Mosaic and Streak in Greenhouse Grown Tomatoes¹

Date of observation	Percentage of plants affected with mosaic and streak ²					
	Best-of-All ³			John Baer ³		
	Mosaic	Streak	Control	Mosaic	Streak	Control
February 6	5	4	0	4	5	0
March 4	5	12	0	16	10	5
March 12	5	16	0	16	50	10
March 15	5	28	0	24	50	35
March 21	25	44	0	52	75	35
March 26	25	56	0	56	90	50
April 4	60	68	0	100	100	50
April 10	70	84	8			65
April 22	85	96	8			90
May 2	100	100	8			100
						16
						16
						28

¹ Sixty-five tomato plants set in each of four ground benches January 5, 1930. Plants were spaced 16 by 18 inches, and tied and pruned according to common horticultural practices.

² One plant of each variety in each bed was inoculated with the mosaic or streak viruses January 23, 1930. The diseases were spread naturally to other plants through cultural practices such as tying, pruning, and watering.

³ Twenty or 25 plants of each variety were set in each bed.

ripened somewhat earlier than did the fruit on healthy plants. The disease spread from the inoculated plants to all the other plants in the bed by April 22 to May 15 through the handling of the plants in cultural practices (Fig. 8). The effect of streak on yields produced during the spring of 1929 is shown in Table 10. These results show that streak infection reduced the average number of fruits per plant 13.3 per cent and the average weight of fruit per plant 20.5 per cent. During the season of 1929 a few plants in the uninoculated beds became affected with streak near the end of the growing season.

The tests were varied in 1930 to the extent that 20 to 25 plants each of the Best-of-All (Sutton's), John Baer, and Marglobe varieties were planted in each bed, and the plants in one bed inoculated with the tobacco mosaic and the plants in another bed inoculated with the streak viruses. The other two beds in which streak-infected plants had been grown the previous season were used to grow the virus-free plants (Fig. 7). Data were collected to determine the rate of spread of the viruses through cultural practices since only three plants in each bed were inoculated January 23, 1930 (Table 11). The effect of streak on the growth of plants compared with the growth produced by the virus-free plants is shown in Figures 7 and 8.

The plants in the two beds free from inoculated plants remained free from mosaic and streak until about one-half of the crop had been harvested, at which time all of the plants in the inoculated beds had become infected with the streak or mosaic viruses by spread through cultural practices (Table 11).

As in the previous year streak caused a marked reduction in yield of fruit, the 1930 crops of the Best-of-All variety showing a reduction of 33 to 44 per cent in the number of fruits and 41 to 44 per cent in the weight of fruit per plant (Table 12). The tobacco-mosaic-infected plants yielded 15 per cent less fruit and 10 per cent less weight of fruit per plant than was obtained from the healthy plants.

A test was made on Best-of-All (Sutton's) tomato plants in a ground bed during the spring of 1931 to determine the rate of spread and economic importance of the mottle disease. One plant in a bed of 70 tomatoes was inoculated with the potato latent virus on March 14. The disease spread by cultural practices to all the plants in this bed by May 1, 1931 and appeared to produce little detrimental effect in the plants as shown by practically no reduction in yield from diseased plants compared with the yield from healthy plants (Table 4).

Table 12. Results of Experiments to Determine the Effect of Viruses on the Yield of Greenhouse Tomatoes. Pullman, Washington, 1930¹

Variety and condition of plants ²	No. of plants	Total yield		Average production per plant				
		No. of fruits	Weight of fruits Pounds	No. of fruits	Percentage reduction	Weight of fruits Pounds	Percentage reduction	Average weight per fruit
Best-of-All								
Healthy	25	744	141	29.8	—	5.64	—	0.189
Healthy	16	548	108	34.2	—	6.74	—	0.188
"Streak" infected	25	445	90	17.8	44.4	3.59	42.1	0.202
Mosaic infected	20	543	112	27.2	15.0	5.60	10.0	0.206
John Baer								
Healthy	20	285	81	14.3	—	4.04	—	0.284
"Streak" infected	20	189	45	9.5	33.6	2.25	44.4	0.238
Marglobe								
Healthy	20	293	87	14.7	—	4.34	—	0.296
"Streak" infected	20	173	51	8.7	40.8	2.55	41.3	0.294

¹ Plants set in beds January 5, 1930.

² One plant of each variety in each of two beds was inoculated with the mosaic or streak viruses on January 23, 1930. These diseases were spread by cultural practices to all plants in the inoculated beds as shown in Table 8.

Control of the Mosaic, Mottle, and Streak Diseases

Most evidence shows that these diseases are not carried in the seed; however, it is advisable to select seed from disease-free plants.

These diseases are spread very rapidly from diseased plants to healthy ones by mechanical contact and by workmen handling the plants. Diseased plants should be removed from the beds or tagged so that they will not come in contact with healthy plants or be handled by the workmen. The hands should be washed with soap and water after handling a diseased plant and at frequent intervals while working with tomato plants.

The tobacco-mosaic virus may be carried in common brands of smoking and chewing tobacco, and be transmitted from the moistened tobacco to tomato plants. Accordingly workmen should not use tobacco, especially cigarette and chewing tobacco, while working with tomato plants.

The mottle disease may be introduced into tomatoes by workmen handling potatoes previous to working with tomato plants, and this virus may be inactivated on the hands by washing with soap and water following the handling of potatoes.

The mottle disease may be introduced into tomatoes by volunteer potato plants growing in the soil with tomatoes; therefore, only soil that is known to be free from volunteer potatoes should be used.

A large number of weeds and cultivated plants may act as carriers of the mottle and mosaic viruses. Such affected plants should be observed and destroyed.

Rotation with some other crop such as chrysanthemums is advisable so that tomatoes are grown in the benches for only half the year. The tobacco-mosaic virus can probably remain active in diseased plant tissue as long as the plant tissue is undecayed in the soil, while the mottle and accordingly the streak viruses may remain active in undecayed plant tissue for three or four weeks following the removal of diseased plants.

Some insects, especially aphids, are capable of transmitting tobacco mosaic from diseased to healthy plants, while no insects have been found that are capable of spreading the mottle or streak diseases. The control of insects by frequent fumigation is advisable.

SUMMARY

The three virous diseases, mosaic, streak, and mottle, are the most commonly found virous troubles of greenhouse-grown tomatoes in Washington, while streak is the most important of the three.

Tests with seed collected from tomato plants affected with common mosaic, mottle, and streak showed that these viruses were not carried in the seed.

The mosaic, mottle, and streak viruses are very readily transmitted by mechanical contact of injured portions of diseased plants with a healthy plant. Frequent washing of the hands by the workmen while working with tomatoes reduces the rate of spread of these viruses.

The mosaic virus may be spread to tomato plants by workmen using tobacco.

The mottle virus may be spread to tomato plants from volunteer potato plants in the soil or by workmen handling potatoes previous to working with the tomato plants.

The mottle and mosaic viruses may be present in a number of different species of weeds and cultivated plants from which they may spread to tomato plants.

Tobacco mosaic remained active in mosaic- or streak-infected tomato tissue in the soil for nine weeks and probably remains active as long as the diseased plant tissue remains undecayed. Less than one per cent of healthy tomato plants, placed in soil in which portions of streak or mosaic plant tissue had been stored for 61 days, contracted the mosaic disease.

The mottle virus as a component of the streak disease was inactivated in infected plant tissue stored in the soil for three to four weeks.

Insects, especially aphids, are able to transmit tomato mosaic from plant to plant. No insects have been found to be able to transmit the mottle or streak diseases.

Tests showed that the presence of the mottle, mosaic, or streak diseases may reduce the yields of fruit 1.8, 15.0, and 44.4 per cent respectively. Observations lead to the conclusion that the streak disease may cause greater losses, depending upon the introduction of the disease on the tomato plants early in their development.

Control methods for the reduction of losses include: avoidance of mechanical contact of diseased and healthy plants; care by workmen not to handle diseased plants while working with healthy plants; frequent washing of hands of workmen with soap and water; removal

of diseased plants from the beds; avoidance of the use of tobacco while working with tomato plants; selection of soil in which there will be no volunteer potatoes; avoidance of handling potatoes previous to working with tomatoes or washing hands thoroughly with soap and water after handling potatoes; destruction of any of the large number of weeds and cultivated plants that may act as carriers of the mottle and mosaic viruses; rotation of crops so that tomatoes are grown in the benches for only half the year followed by some other crop the other half; and control of insects by frequent fumigation.

LITERATURE CITED

1. Ainsworth, G. C., Berkeley, G. H., and Caldwell, J. A comparison of English and Canadian tomato virus diseases. *Ann. Appl. Biol.* **21**: 566-580. 1934.
2. Allard, H. A. The mosaic disease of tobacco. U. S. Dept. Agr. Bul. 40. 1914.
3. ———. Further studies on the mosaic disease of tobacco. *Jour. Agr. Res.* **10**: 615-632. 1917.
4. Berkeley, G. H. and Madden, H. O. Transmission of streak and mosaic diseases of tomato through seed. *Sci. Agr.* **13**: 455-458. 1933.
5. Blewley, W. F. and Corbett, W. The control of cucumber and tomato mosaic diseases in glasshouses by the use of clean seed. *Ann. Appl. Biol.* **17**: 260-265. 1930.
6. Burnett, G. The longevity of the latent and veinbanding viruses of potato in dried plant tissue. *Phytopath.* **24**: 215-227. 1934.
7. ———. Stunt—a virosis of delphinium. *Phytopath.* **24**: 467-481. 1934.
8. ——— and Jones, L. K. The effect of certain potato and tobacco viruses on tomato plants. *Wash. Agr. Exp. Sta. Bul.* 259. 1931.
9. Cleveland, C. R. The relation of insects to the transmission of potato leaf roll and tomato mosaic in Indiana. *Purdue Agr. Exp. Sta. Bul.* 351. 1931.
10. Doolittle, S. P. Soil transmission of tomato mosaic and streak in the greenhouse. *Phytopath. (Abstract)* **18**: 155. 1928.
11. Elmer, O. H. Transmissibility and pathological effects of the mosaic disease. *Iowa Agr. Exp. Sta. Res. Bul.* 82. 1925.
12. Grant, T. J. The host range and behavior of the ordinary tobacco-mosaic virus. *Phytopath.* **24**: 311-336. 1934.
13. Heuberger, J. W. and Norton, J. B. S. The mosaic disease of tomatoes. *Maryland Agr. Exp. Sta. Bul.* 345. 1933.
14. Hoggan, I. A. Aphid transmission of plant viruses. *Phytopath. (Abstract)*, **20**: 133. 1930.

15. Holmes, F. O. Symptoms of tobacco mosaic disease. Contrib. Boyce Thompson Inst. **4**: 323-375. 1932.
16. Jensen, J. H. Isolation of yellow-mosaic viruses from plants infected with tobacco mosaic. Phytopath. **23**: 964-974. 1933.
17. Johnson, James. The classification of plant viruses. Wis. Agr. Exp. Sta. Res. Bul. 76. 1927.
18. Johnson, J. and Ogden, W. B. The overwintering of the tobacco mosaic virus. Wis. Agr. Exp. Sta. Res. Bul. 95. 1929.
19. Jones, L. K., Anderson, E. J., and Burnett, G. The latent virus of potatoes. Phytopath. Zeitschrift **7**: 93-115. 1934.
20. McClean, A. P. D. Bunchy top disease of the tomato. Union South Africa Dept. Agr. Sci. Bul. 100. 1931.
21. McWhorter, F. P. Additional notes on the English form of tomato spotted wilt in Oregon. Plant Dis. Reporter **18**: 48. 1934.
22. Morgendorff, N. "Fern-leaf" of tomato. Phytopath. **20**: 25-46. 1930.
23. Olitsky, P. K. The transfer of tobacco and tomato mosaic disease by *Pseudococcus citri*. Science **2**: 442. 1925.
24. Samuel, G., Bald, J. G., and Pittman, H. A. "Spotted wilt" of tomatoes. Australia Council for Sci. and Ind. Res. Bul. 44. 1930.
25. Samuel, G., Bald, J. G., and Eardley, C. M. "Big Bud," a virus disease of the tomato. Phytopath. **23**: 641-653. 1933.
26. Schultz, E. S. et al. Resistance of potato to mosaic and other virus diseases. Phytopath. **24**: 116-132. 1934.
27. Severin, H. H. P. Additional host plants of curly top. Hilgardia **3**: 595-629. 1929.
28. Smith, K. M. and Brooks, F. T. Recent advances in the study of plant viruses. P. Blakiston's Son & Co. Philadelphia. 1934.
29. Valleau, W. D. and Johnson, E. M. Commercial tobaccos and cured leaf as a source of mosaic disease in tobacco. Phytopath. **17**: 513-522. 1927.
30. Valleau, W. D. and Johnson, E. M. Some possible causes of streak in tomatoes. Phytopath. **20**: 831-848. 1930.
31. Young, P. A. and Morris, H. E. Witches' broom of potatoes and tomatoes. Jour. Agr. Res. **36**: 835-854. 1928.